THE EQUATORIAL ROTATION VELOCITY OF THE PHOTOSPHERE IS MEASURED TO BE THE SAME AS SUNSPOTS

by

L. Svalgaard, P.H. Scherrer, J.M. Wilcox

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The equatorial rotation rate of the photosphere was measured at the Stanford Solar Observatory during 1976-1978 using spectroscopic data. The following points are made: 1) Scattered light has a large influence and must be taken into account properly. 2) When this is done we find that the rotation rate from Doppler shifts agrees very well with the rate found for sunspots. 3) Short-term fluctuations in rotation rate (i.e. from day to day) are less than ±15 m/s and are thus within observational errors.

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Abstract

The equatorial rotation rate of the photosphere was measured at the Stanford Solar Observatory during 1976-1978 using spectroscopic data. The following points are made: 1) Scattered light has a large influence and must be taken into account properly. 2) When this is done we find that the rotation rate from Doppler shifts agrees very well with the rate found for sunspots. 3) Short-term fluctuations in rotation rate (i.e. from day to day) are less than ± 15 m/s and are thus within observational errors.

The solar rotation has been observed at the Stanford Solar Observatory during the interval 1976-1978. It is found that the equatorial rotation rate obtained from spectroscopic observations is the same as the equatorial rate found by Newton and Nunn (1951) for sunspots.

The Stanford Solar Observatory consists of a coelostat approximately 8 m above the ground that forms an image approximately 6 cm in diameter that is fed into a Babcock solar magnetograph. The magnetograph is connedted to a 22.9 m vertical Littrow spectrograph. The spectrograph optics are similar to those at the Mt. Wilson Observatory. The observations to be reported were obtained using the Doppler compensator of the magnetograph with the line FeI λ 5250Å with a square aperture of size 3', i.e.

1/10 of the solar disk diameter. The Stanford Solar Observatory has been described by Scherrer *et al.* (1977).

For each day we computed the average rotation velocity in the center half of the area of the solar disk, i.e. within a circle of radius 0.7 $R_{\odot}$. This average velocity was converted to an equatorial rotation velocity assuming the form of the differential rotation given by Newton and Nunn (1951). The computed equatorial velocity is rather insensitive to the precise form of differential rotation assumed.

Figure 1 shows daily values of the equatorial rotation velocity as measured, without the correction for scattered light that will be described below. Each vertical shift in Figure 1 corresponds to the time at which mirrors and/or the objective lens were cleaned or a new mirror was installed. The abrupt increase in measured rotation velocity at the time of cleaning of the optics suggests that scattered light has an important influence on the measured velocities, as was first pointed out by DeLury (1916).

How can one correct the observed rotation velocity for the effect of scattered light? We measured the intensity of scattered light 2' off the solar disk. We started the investigation on a fine, clear day with clean mirrors and lenses. Figure 2 shows the measured equatorial velocity and the measured intensity at the center of the solar disk as a function of the scattered light 2' off the limb. The points at the left side of Figure 2 were obtained with clean optics. We then put some fine chalk dust on the objective lens, and in this situation of increased scattered light repeated the above measurements to obtain another point in Figure 2. We then put more fine dust on the objective lens and again measured rotation velocity and intensity as a function of scattered light. Repeating this process gave the several points in Figure 2 which were fitted with a straight line as shown. This straight line can be described with the equation $V_0 = 2025 - 24S_2$ m/s, where V_0 is the equatorial rotation velocity and S_2 is the scattered light measured 2' off the limb in

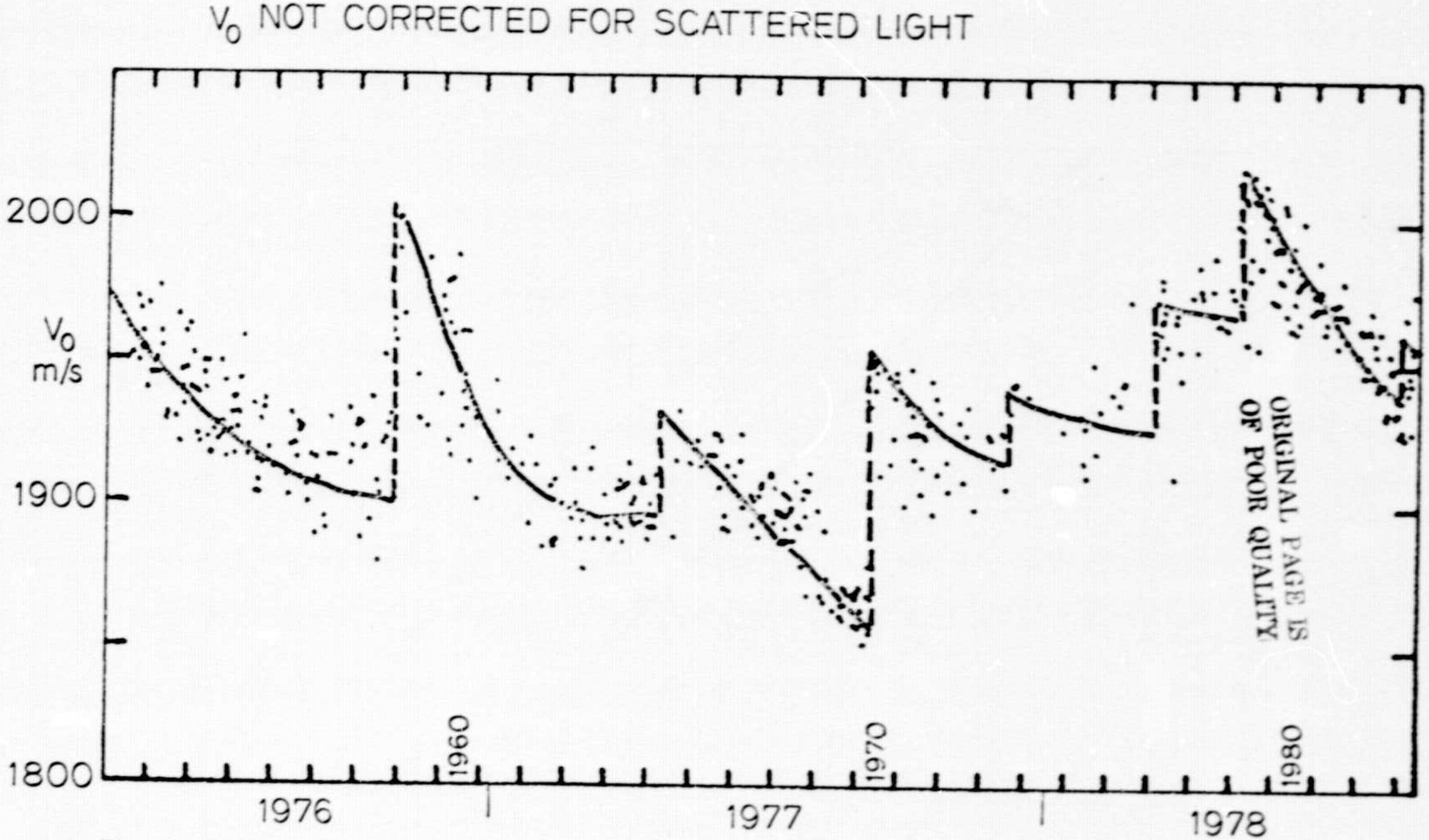

Fig. 1 Daily values of equatorial rotation velocity determined from spectroscopic observations. These values have not been corrected for effects of scattered light. Each vertical excursion of the curve is at the time when a mirror or lens was cleaned or replaced. For comparison, the equatorial roation velocity for sunspots determined by Newton and Nunn (1951) was 2035 m/s.

percent of central intensity of the disk. If the straight line is extrapolated to zero scattered light an equatorial rotation velocity of 2025 m/s is found. For comparison the equatorial velocity of sunspots found by Newton and Nunn (1951) was 2035 m/s.

The straight line in Figure 2 indicates that 1% scattered light 2' off the limb reduces the measured rotational velocity by about 1%. On the disk scattered light is typically four times larger. The dashed curve in Figure 2 shows the measured intensity at the center of the disk as a function of scattered light 2' off the limb. This curve is described by $I_o = 4250\ e^{-0.2S_2}$, where I_o is the measured intensity at the center of the disk. The measured intensity - corrected for varying airmass and solar distance - for each observation can thus be used to correct for the influence of scattered light. We conclude that it is essential that each such observation be so corrected.

Figure 3 shows the daily values of equatorial rotation velocity after the correction for scattered light has been made. During the interval of our observations 1976-78 the corrected equatorial rotation was constant within less than 1%, and indistinguishable from the rotation velocity of spots obtained by Newton and Nunn (1951).

A detailed comprehensive analysis of the effects of scattered light on solar observations is in preparation, and a collaborative investigation of relation of the present results to previous observations is in progress.

Acknowledgements

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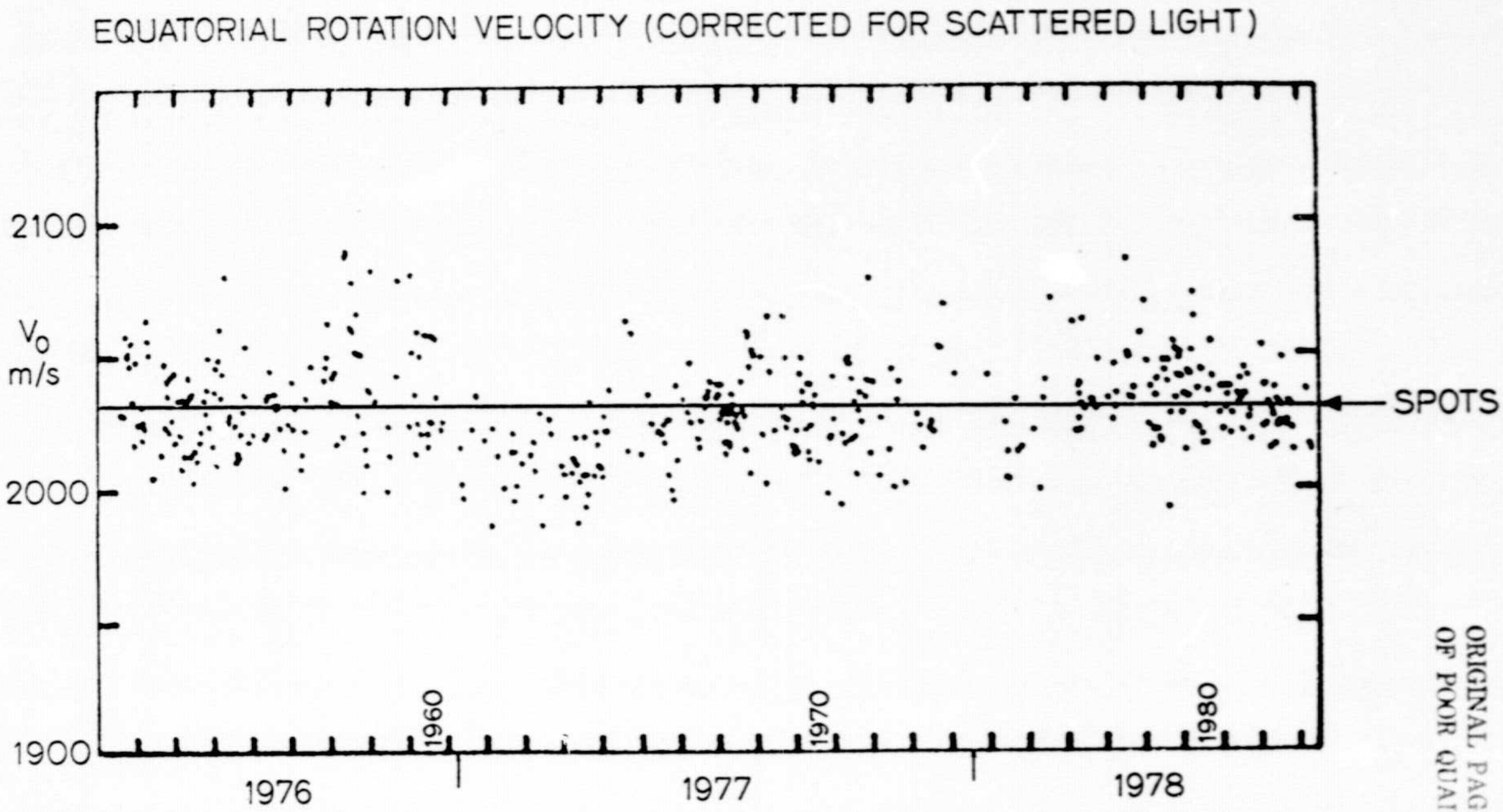

Fig. 3 Daily values of the equatorial rotation velocity corrected for scattered light. During the interval of observations in 1976-78 the rotation velocity was constant to within less than 1%, and was the same as the velocity determined for sunspots by Newton and Nunn (1951).

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